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Total Adaptation to Prismatic Displacement in the Absence of Reafference[1]

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Held and his associates have elaborated a theory to account for adaptation tc prismatic displacement, invoking the necessity for "reafference" (Held & Friedman, 1963). Reafference is defined as "fedback stimulation correlated with the self-produced movements of the stimulated organism" and is stated to be "essential for readjustment of visual-motor coordination during rearrangement" (Hein and Held, 1962). Recent studies, however, have been critical of this theory, (Weinstein, Sersen, and Weinstein, 1964; Weinstein, Sersen, Fisher and Weisinger, 1964) and it has been shown that positive adaptation can occur in the absence of self-induced movement. These authors have stressed instead the sufficiency of informational feedback in the production of adaptation. They indicate that the effectiveness of reafference may lie solely in its concomitant informational component, and that other forms of informational feedback, independent of bodily movements, can also produce adaptation. Thus, whereas Held and his associates assign a qualitative distinction to information derivable from reafference, this information can instead be considered as only quantitatively different from other sources of informational fedback.

A recent study (Wallach, Kravitz, and Lindauer, 1963) has demonstrated large degrees of positive adaptation after very brief periods of exposure to prisms under "passive conditions." Although they failed to find a correlation between magnitude of head movements and degree of adaptation, proponents of reafference theory might argue that lack of correlation between head movements and degree of adaptation in no way demonstrates that head movements were not responsible for the adaptation. Furthermore, neither this nor any previous study, has shown full and exact (100%) adaptation in the absence of sensorimotor fedback.

Although Held and his associates formerly accepted lesser degrees of adaptation as verification of reafference theory. (Held and Gottlieb, 1958; Held and Hein, 1958; Held and Schlank, 1959), they have subsequently recognized that such lesser adaptation can occur in the absence of reafference. It is now maintained that only reafference can produce "full and exact compensation" for the errors initially induced by rearrangement (Held and Freedman, 1963).

UNPUBLISHED PRELIMINARY DATA

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The purpose of the present study, therefore, was to determine whether 100% adaptation to prismatic displacement can be achieved without any bodily movements.

Method

Subjects. There were 46 Ss with normal vision, 30 men, and 16 women, consisting of medical technicians, medical students, physicians, nurses, and other hospital employees.

Apparatus and Procedure. The apparatus consisted of an adjustable bite bar for a standing S. A dim target light above a large protractor, was located approximately at S's eye level, 61.0 cm. from the right eye. The bite bar, target light, and protractor were adjustable to S's height. The protractor, the pointing surface for S, was attached 17.8 cm. below the target light and parallel to the floor. S bit into the bite bar, an aluminum bar 2.5 cm. wide covered with dental wax. His left eye was occluded with an eye patch, a pointer was attached to his right index finger, and the room was darkened. E then raised a curtain revealing the dim target light. S attempted to place his right index finger on the lower surface of the protractor directly below the light. After each judgment S closed his eyes while E recorded the position of the pointer to the nearest 0.5°. Following the judgment, S returned his right arm to his side. The mean of ten such judgments constituted the pre-exposure score.[2]

Following the ten pre-exposure judgments, the room was illuminated and the bite bar was rotated 90° downward, enabling S to see his feet. The eye patch remained in place over the left eye, and a 13 diopter base-left, or base-right laterally displacing prism was placed over S's right eye. S then observed his feet for ten minutes. Following this exposure, S closed his eyes while the prism was removed and the bite bar was returned to its original position. The room was again darkened, and the pointing task was repeated for four trials.[2] The mean of these four judgments constituted the postexposure score.. The exposure period and the postexposure testing were repeated from one to ten additional times. Most of the Ss who continued beyond three trials required one or more rest periods. During the rest period, S sat in a chair with eyes closed for approximately 5 min.

Testing was discontinued from one to seven trials after S achieved 100% adaptation, or failed to approach 100% adaptation in several trials. Testing was also discontinued if S became ill (fainted, became dizzy, or nauseated) or was unwilling to continue.

Results

The purpose of this experiment was to determine whether "full and exact compensation" to prismatic displacement could be achieved in the absence of movement of the head or body. Such compensation was demonstrated by eight Ss whose data are presented in Fig. 1. Table 1 gives the data for the remaining Ss who did not reach 100% adaptation.

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Place Table 1 and Figure 1 about here.

An analysis of variance was performed for each S, comparing his pre- and postexposure means. Utilizing the pooled variance, a Dunnett's test compared each postexposure mean with zero per cent adaptation (pre-exposure mean) and with 100% adaptation (pre-exposure mean plus 7.42°).

In addition to the 8 Ss reaching 100% adaptation, 15 Ss achieved adaptation which was significantly greater than zero, ranging from 18% to 90%. Of these 15 Ss, 4 achieved adaptation which did not differ significantly from 100%.

All 15 Ss who achieved positive adaptation did so within three ten-minute exposure periods, 6 within the first trial. Of the 8 Ss who achieved 100% adaptation, two each achieved it within trials two, three, four, and five (Fig. 1). Of these eight Ss 7 achieved significant positive adaptation by the first trial, the other by the third trial.

Discussion

Eight Ss (17%) achieved 100% adaptation after prismatic exposure, despite the fact that the procedure employed was a difficult one for S to maintain, and caused several Ss to withdraw because of the extreme discomfort. Furthermore, not only was "full and exact" adaptation in the absence of reafference demonstrated, it was achieved after brief periods of exposure. Thus, all 8 of the Ss achieving 100% adaptation did so within 30 minutes of exposure time; by contrast, the 8 Ss in the Held and Bossom study (1961), for example, required from a minimum of one hour to twenty-three hours of exposure extending over four days to achieve 100% adaptation. Similarly, the Ss of Hay and Pick (1963) required several days of reafference to achieve high levels of adaptation to prisms.

Since demonstration of 100% adaptation without reafference was the critical test of the theory, only Ss who demonstrated rapid increments of adaptation were tested repeatedly. The possibility that continued exposure trials for those Ss who did not show an early rapid rise in adaptation might have resulted in 100% adaptation, is illustrated by S 37 (Table 1). Although this S demonstrated negative adaptation for trials one and two, he achieved 90% positive adaptation by the fourth trial, a value not significantly less than 100%.

In a previous study (Weinstein, Sersen, Fisher, and Weisinger, 1964) we have proposed that informational feedback is the critical factor in the production of adaptation to prismatic displacement. We believe that the present procedure may have provided a more efficient means of informational fedback than those previously employed. The discrepancy between the displaced view of one's own feet and long-established postural cues would be expected to provide maximal information concerning the displacing nature of the prisms and, indeed, did yield full and exact compensation.

Although it has been recognized that other factors may be responsible for minor degrees of adaptation it has been emphasized that for full and exact compensation, reafference is the crucial factor (Held & Freedman, 1963). The results of the present study, however, have shown that informational fedback independent of reafference can also produce full and exact compensation, and thus support our position that that reafference is only one among many sources of information sufficient to produce adaptation.

Held and Freedman have also maintained that reafference is necessary for sensorimotor development in the neonate. "Demonstration of complete compensation is of crucial importance in bridging the gap between adaptation in the adult and original development in the newborn infant. When it can be shown that adaptation proceeds to a stable end state which corresponds to accurate orientation in the environment, then it is conceivable that the same process operates in the development of coordination in the newborn infant" (1963, p. 2). We agree with this position but further propose that it is the informational fedback which we have shown to be responsible for adaptation to rearrangement that may also be critical in sensorimotor development.

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Footnotes

1. This study was supported by NASA through Grant NsG-489 to the senior author. Additional support was obtained from VRA through Grant RD-427.

2. For the first two Ss tested, the pre- and postexposure scores consisted of eight such judgments. It was noted, however, that adaptation decreased significantly from the first four to the final four judgments. Hence, subsequent Ss were tested as described in the text.

Table 1

Per Cent Adaptation as a Function of Exposure Trials

Trials

S	1	2	3	S	1	2	3	4	5	6	7	8	9
1	-32			20	16	2	3						
2	-11			21	-12	15	36[a]	14					
3	-7			22	-21	-18[a]	6	-7					
4	23	-16		23	33	-10	-15	-18					
5	23	32[a]		24	7	34	-35	27					
6	-81[a]	-57[a]		25	40[b]	62[ab]	28	40[b]					
7	-5	-29[a]		26	-4	18	25[a]	32					
8	-4	-35[a]		27	1	63[a]	18[a]	51					
9	3	-28		28	16	0	27	27					
10	-3	-22		29	45[a]	40[a]	-20	18					
11	37[a]	19		30	20	8	27	29	22				
12	3	34		31	24	22	39[a]	29	39[a]				
13	-1	4		32	21	-16	18	-24	2				
14	5	4	-26[a]	33	57[a]	90[ab]	33[a]	38[a]	30				
15	13	-19	18	34	4	48	37[a]	40[a]	35[a]	20			
16	-44[a]	-70[a]	-71[a]	35	32	34	44[a]	45[a]	62[a]	49[a]			
17	-47[a]	-45[a]	-18	36	10	32[a]	52[a]	38[a]	60	80[a]	40[a]		
18	-32	-36	-32	37	-35[a]	-18	9	90[ab]	71[a]	58[a]	34[a]	37[a]	
19	55[a]	58[a]	33	38	39[a]	49[a]	60	44[a]	89[ab]	79[ab]	57[a]	72[ab]	64[ab]

a. Different from 0%, $p < .05$.

b. Not significantly different from 100% ($p > .05$).

Fig. 1 Course of adaptation for Ss achieving full and exact compensation. For Ss 2, 3, 4, 6, and 7 the final postexposure test was made following a 10 min. period during which S, without prisms on, either stood in the apparatus or sat passively.